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A METHOD for DETERMINING INTAKE CHARACTERISTICS of IRRIGATION FURROWS

U.S. DEPT. OF AGRICULTURE
MAR 1959
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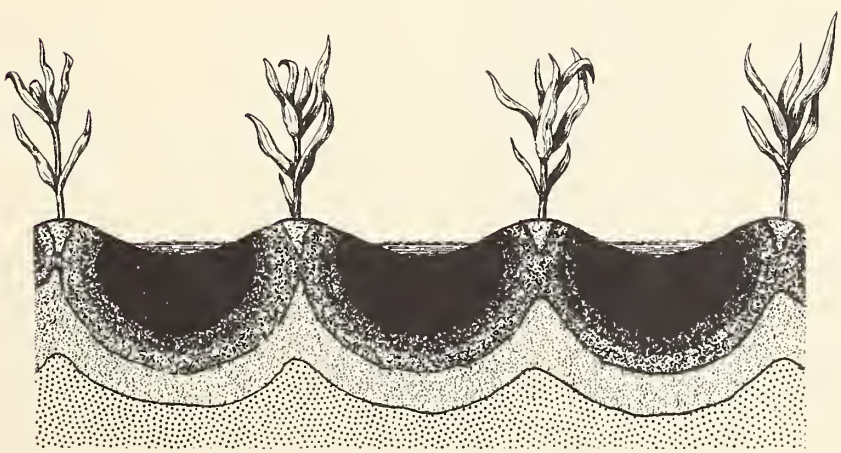

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Foreword

In January 1955 the Soil Conservation Service, United States Department of Agriculture, and the Western Soil and Water Conservation Research Branch (now a Division) of the Agricultural Research Service, USDA, established a joint Intake Committee to study the use of cylinder infiltrometers. After about a year of investigation and study, the committee completed the assignment by preparing a report entitled 'The Use of Cylinder Infiltrometers to Determine the Intake Characteristics of Irrigated Soils." This report was published by the two Services in May 1956 as ARS 41-7, a publication of the ARS Branch.

Subsequent to the publication of the report on cylinder infiltrometers, the Intake Committee was asked to review the methods and techniques used in measuring the intake of water from irrigation furrows and to recommend a standard procedure for making such measurements. The committee studied the methods and techniques currently used and prepared a tentative draft of a standardized procedure for review by technicians of both agencies. Following this, the committee met in Fort Collins, Colo., to consider the suggestions that had been made and to prepare a final report. The standardized procedure presented in this report is respectfully submitted by the Intake Committee as a recommended procedure for field use.

A method for DETERMINING INTAKE CHARACTERISTICS *of* IRRIGATION FURROWS

by

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INTRODUCTION

The rate at which irrigation water, when applied on the surface of a field, is absorbed into the soil is called the "intake rate." Intake rates may be limited by how fast water will move through the air-soil interface (infiltration) or by the rate at which the water will move through the soil mass (hydraulic conductivity). When using furrow and corrugation methods of irrigation, only a portion of the field surface is covered with water. All of the water that infiltrates into the soil must enter through the wetted area at the bottom and along the sides of the furrows. The rate of entry is called the "furrow intake rate." A knowledge of furrow intake characteristics is needed for the design and operation of irrigation systems that involve the application of water by the furrow or corrugation methods.

Furrow intake characteristics can be determined from inflow-outflow measurements of representative furrows under field irrigation conditions. The rate of inflow into a furrow minus the rate of outflow from the furrow, at any time, is equal to the rate of intake into the soil plus the rate of change in channel storage. However, after the initial filling period, the rate of change in channel storage is small and may be disregarded. The difference between the rate of inflow and the rate of outflow at any given time, therefore, can be assumed to represent the furrow intake rate at that time.

Inflow and outflow rates usually are recorded in units of gallons per minute. The intake rate by the soil, being the difference between inflow and outflow, likewise is expressed as gallons per minute. Also, the intake is a function of the length of furrow between the inflow and outflow stations. The intake rate, therefore, is gallons per minute in a particular length of furrow. In order to be able to compare intake rates, it is necessary to reduce all rates to a standard, or unit, furrow length. For this reason, it has now become common practice to record furrow intake rates in units of gallons per minute per hundred feet of furrow.

Furrow intake studies can be made on furrow sections of various length. For ease in analysis, it is desirable to use sections short enough so that the rate of advance is essentially uniform. Another advantage of short sections is that data on the initial part of the intake rate curve can be secured. However, some soils take water so slowly that on short furrow sections the reduction in flow between the inflow and outflow stations (intake) is too small to be measured accurately. Sections long enough to produce substantial differences between inflow and outflow rates should be used for studies on all soils. Experience has indicated that satisfactory determinations of intake rates usually can be made for normal uniform soils by using furrow section lengths about as follows:

Fine textured soils	300 to 800 feet
Medium textured soils	200 to 400 feet
Coarse textured soils	100 to 200 feet

Poor soil structure, stratified subsoil, or other factors that tend to reduce intake rates may require the use of longer test sections.

To reduce the effects of inaccuracies in water measurement, furrow lengths can be increased without increasing the time of advance from the inflow station to the outflow station. Figure 1 shows how this can be accomplished by measuring flows into and out of groups of two or more relatively short furrows. The rate of flow into the individual furrows in a group should be adjusted so that all furrow streams have about the same rate of advance.

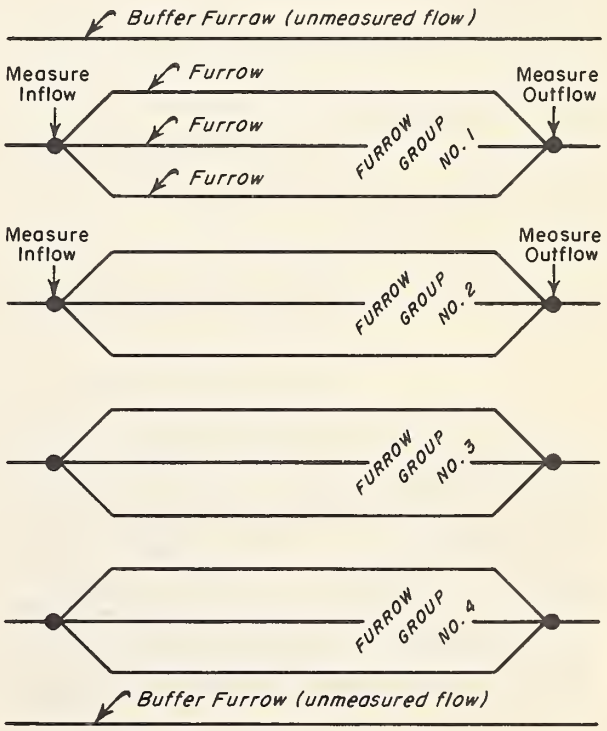

FIGURE 1 : *A suggested multiple furrow layout for furrow intake tests on low intake rate soils.*

SITE SELECTION

Furrow tests to determine the intake characteristics of irrigated soils must be made on carefully selected sites that are representative of the conditions to be evaluated. Indiscriminate studies on complex soil patterns may have some on-site benefits but seldom have any predictive value. Competent soil scientists should assist in the selection of test sites. The following procedure is suggested:

1. Select a site that is representative of a particular soil mapping unit. The site selected should have no recognizable difference in soil throughout the length of furrow that is to be studied. The furrows should have a uniform cross section and a uniform grade between the inflow and outflow measuring points.

2. Examine and describe the soil profile. Determine texture and textural changes. Describe the soil structure. Check for the presence of a plow pan or other compaction that might influence intake. Conditions in the top foot are of particular importance. Make notes of saline or alkaline conditions encountered. Figure 2 shows the standard soil description form used in the Soil Conservation Service. This, or some similar form, should be used to record the characteristics of each test site.

3. Make estimate of soil moisture, or secure samples for soil moisture determinations. It is recommended that, where feasible, studies be made when moisture conditions indicate that normal irrigation applications are needed. Moisture conditions should be recorded as percentages of the available moisture-holding capacity.

FRONT

Soil type	Parrott fine sandy loam 1S54		Date 6-23-57	Stop No.	Soil type
Classification	Brown		Area Gooding Co. Idaho		
Location	S14, T6S, R14E			Elev. 3550	
N. veg. (or crop)	Sugar Beets		Climate Temperate - Semi Arid		
Parent material	Mixed alluvium				
Physiography	Terrace				
Relief	Moderate	Drainage Well drained		Salt or alkali None	
Elevation		Gr. water Deep		Stoniness None	
Slope	1 %	Moisture Mod. dry			
Aspect		Root distrib. Unrestricted			
Erosion	Slight				
Permeability	Moderately rapid				File No.
Additional notes					

SCS-232A-Soil Description—Rev. 7-15-56 GPO 1956 O-F—395158

BACK

Horizon	Depth	Color		Texture	Structure	Consistence			Reaction	Boundary
		Dry	Moist			Dry	Moist	Wet		
A1p	0-7	10 YR 6/2	10 YR 3/2	f.s.l.	1fgr	ds	mfr	wso wpo		
Ac1	7-14	10 YR 6/3	10 YR 3/3	f.s.l.	1cpr 1fgr	ds	mfr	wso wpo		
Ac2	14-30	10 YR 7/3	10 YR 4/3	f.s.l.	sg	ds	mvfr	wso wpo		
C	30-50+	10YR 7/4	10 YR 4/4	f.s.l.	sg	dl	ml	wso wpo		

FIGURE 2: *Form SCS-232A used to describe soil at test site.*

4. Examine and describe the condition of the furrows--freshly cultivated, cloddy, blocked with trash or vegetation, smoothed out by previous irrigation, etc. Determine how many times the field has been irrigated since the start of the irrigation season and since the last furrowing operation.

5. When replicated tests are to be made to evaluate the intake characteristics of a particular kind of soil, select the various sites on the basis of essential likeness. The furrows should all have about the same shape. Tests need not be confined to one crop, but tests on corrugated close-growing crops should not be grouped with tests on furrowed clean-cultivated crops. Furrow grades and furrow streams should not vary by more than 50 percent. That is, the steepest furrow grade should be no more than one and a half times the grade of the flattest furrow selected. And the largest stream size used in the replicated tests should be no more than one and a half times the smallest.

FLOW MEASUREMENT

The flow of water in furrows can be measured in several different ways. However, it must be remembered that, no matter what kind of equipment is used, accurate measurements are dependent upon the care with which the measuring devices are installed and operated.

Volumetric Method

Volumetric measurements can be made with a calibrated container and a stopwatch. The water is run into a bucket or other container of known capacity, and the time required for the flow to fill the container is determined with the stopwatch. The flow rate can then be computed from the formula:

$$\text{FLOW (G.P.M.)} = \frac{60 \times \text{CAPACITY OF CONTAINER IN GALLONS}}{\text{NUMBER OF SECONDS TO FILL}}$$

This is the most accurate method known for field measurement of small flows. In addition, it is simple and requires little equipment. Volumetric measurements should be used for all intake studies involving flows of less than 20 gallons per minute. For larger flows, alternate methods of measurement may be used. However, where site conditions permit, the volumetric method is recommended for flows up to about 60 gallons per minute.

If flows are timed carefully with a stopwatch, the timing error should not exceed ±0.2 second. Therefore, ± flow measurements of reasonable accuracy (5 percent error) can be made if the calibrated container used requires at least 4 seconds to fill. A longer filling time usually will provide more reliable data. The 4 second criterion should not be exceeded in making flow measurements for intake studies. Containers that will hold more than 5 gallons are very difficult to handle. Hence, volumetric measurements seldom are used for furrow flows larger than about 75 gallons per minute.

In making volumetric measurements, the water usually should be run through a furrow tube or small flume, cantilevered at the down-stream end to permit free discharge into the container. The down-stream invert of the furrow tube or flume must be at least 1.5 inches above the maximum water surface in the furrow into which it discharges. Figure 3 shows a typical installation.

At inflow measuring stations, furrow tubes usually can be set high enough to insure free discharge conditions. Ponding above the inflow station will not affect the intake computations. However, a ponded area above the outflow station may cause an increase in the furrow intake rate. Therefore, the volumetric method should not be used for outflow measurements where irrigation grades are so low that satisfactory discharge conditions through the furrow tube will cause ponding in more than about 5 percent of the test furrow length. Large furrow tubes or open flumes sometimes can be used to reduce ponding above the outflow station.

Where outflow measurements must be made on slopes too "flat" for satisfactory use of the above-described volumetric procedure, a modified procedure, such as that shown in Figure 4, may be used. With this modified procedure, the water is not discharged directly into the container. Instead, it is allowed to flow into the sump and spill over the lip of the container. The sump is first bailed out until the water surface is below the lip of the calibrated container when the container is held firmly against the bottom of the sump. Then, when the water surface rises to

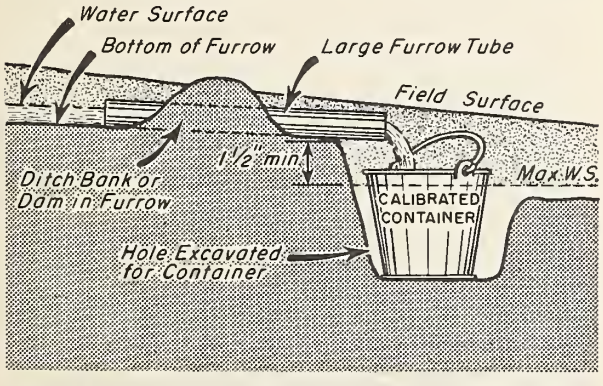

FIGURE 3 : *Typical installation for volumetric measurement of furrow flows.*

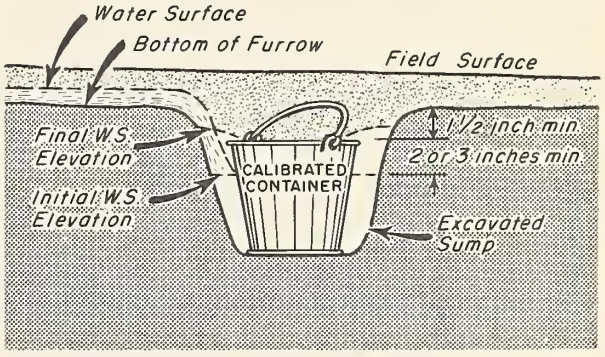

FIGURE 4 : *Typical installation for elimination of ponding in volumetric measurement of furrow flows.*

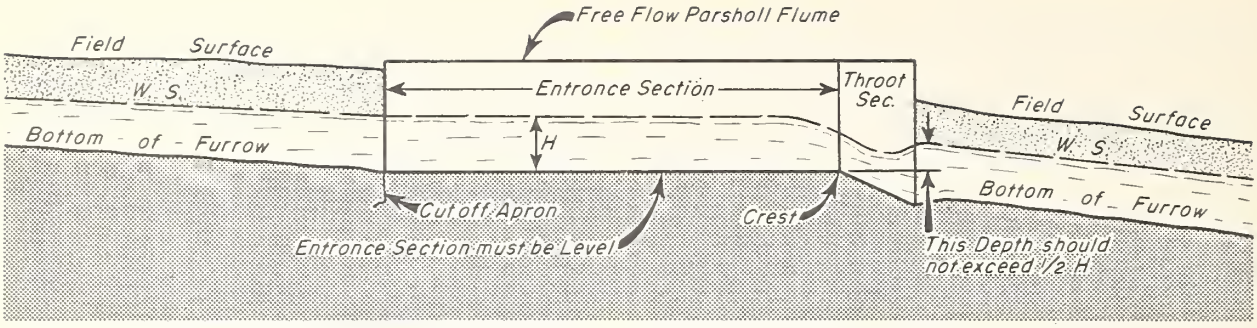

FIGURE 5 : *Typical free-flow Parshall flume installation for measurement of furrow flows.*

the lip of the container, the water will flow into the container and the filling time can be determined with a stopwatch.

As the water surface in the sump always must rise a small distance above the elevation of the lip in order to cause flow into the container, an error of some magnitude is introduced. This error will vary with the amount the cross sectional area of the sump exceeds the area of the top of the container and, also, with the height of the water surface above the lip. Therefore, the excess cross sectional area of the sump must be kept as small as possible and the method used only for flows that will require no less time than 10 seconds to fill the container. For small flows (requiring 20 or more seconds to fill container) and sump areas less than 3 times the area of the container, the introduced error will be negligible.

Satisfactory volumetric flow measurements can be obtained with a wide variety of equipment. However, for general use in furrow intake studies the following items are recommended.

1. Furrow tubes (spiles), 3-inch diameter, 30 inches long. Two required for each furrow. (Tubes used at inflow station should be equipped with slide gates for flow control.)

2. Calibrated water buckets, 3-gallon capacity. Two recommended. (One for use at the inflow station and the other for use at the outflow station.)

3. Stopwatches, registering seconds by 5th of a second. Two recommended.

4. Watch or clock that can be used to determine rates of advance and elapsed flow times to the nearest minute. One required.

5. Standard forms for recording test data.

Parshall Flumes

Parshall flumes can be used for direct measurements of rates of flow. Free-flow Parshall flumes are made with a converging entrance section. The throat section has a sloping floor, designed to produce critical flow conditions at the crest. The flow through the flume is directly related to the water depth measured at a specified point in the level entrance section.

Parshall flumes used for furrow flow measurements are designed for use under free-flow conditions as shown in Figure 5. They usually have throat widths of either 1, 2, or 3 inches. Standard free-flow flumes with a 1-inch throat width can be used to measure flows from 3 to 45 gallons per minute. Two-inch flumes have a capacity range from 5 to 90 gallons per minute. The range for 3-inch flumes is from 15 to over 150 gallons per minute. Construction and hydraulic characteristics of these small flumes are described in Technical Bulletin 61 (1957) of the Colorado Agricultural Experiment Station, "Parshall Measuring Flumes of Small Sizes," by A. R. Robinson.

Parshall flumes, properly installed, will permit satisfactory flow measurements with little loss in head. For example, a 2-inch flume requires an upstream water depth of only 2.7 inches for a 30 gallons per minute discharge, and the drop in the water surface through the flume can be as small as 1.5 inches. For this reason, these flumes are particularly well adapted for use in measuring outflows from furrows on the flatter slopes. However, it must be remembered that these Parshall flumes have been rated under very exact installation conditions and that the rating charts will apply only when field installations, likewise, are carefully made. The entrance section of the flume must be level, both longitudinally and transversely, and the water depth must be precisely measured at the designated point in the entrance section. Leveling or measuring errors as small as 1/16 inch can significantly affect the accuracy of the discharge measurements. Because of these strict installation and operation requirements, Parshall flumes are recommended for use in intake studies only where conditions are unsatisfactory for volumetric measurements of flows. Where Parshall flumes must be used, they should be installed and operated by qualified personnel.

Recommended equipment for making furrow intake studies with Parshall flumes is as follows:

1. Standard free-flow, 2-inch Parshall flumes. Two required for each furrow. (If flows larger than 30 gallons per minute are to be measured, 3-inch flumes may be substituted to reduce head requirements. Three-inch flumes usually will be required for flows larger than 60 gallons per minute.)

2. Watch or clock that can be used to determine rates of advance and elapsed flow times to the nearest minute. One required.

3. Furrow tubes (spiles), 3-inch diameter, 30 inches long, equipped with slide gates, for use in regulating inflow. One required for each test furrow where furrow streams are less than 60 gallons per minute. For larger inflow streams

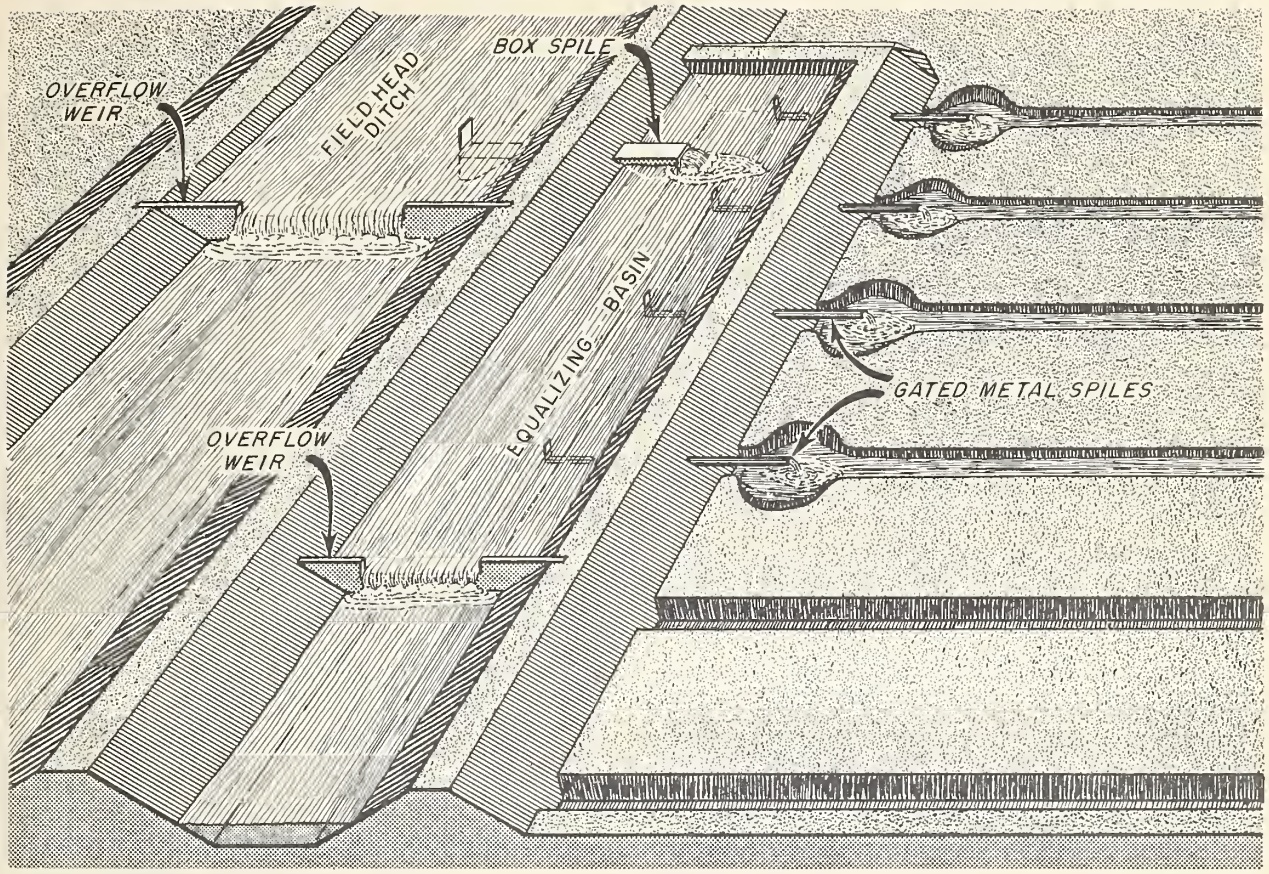

FIGURE 6 : *A suggested method of control to provide constant rates of flow into furrows.*

additional 3-inch spiles, or larger ones, will be required.

4. Small staff gages, graduated in hundredths of feet or tenths of inches to measure depth of flow in flumes. Two required.

5. Small pocket or chalk-line level for use in installing flumes. One required.

6. Standard forms for recording test data.

Other Methods

Other measuring devices, such as orifice plates, triangular-notch weirs, and specially designed flumes, have been used to measure furrow flows. Any device that can be calibrated to provide flow measurements of the required accuracy, without objectionable loss of head or ponding, can be used. As a general rule, satisfactory intake studies can be made if furrow flow measurements are accurate to within 5 percent. Flows can be measured volumetrically or with Parshall flumes well within this degree of accuracy.

Insufficient data are available on the hydraulic characteristics of other measuring devices to permit them to be recommended for widespread use in furrow intake studies. Among the several devices, however, that are now being studied in hydraulics laboratories and may prove acceptable, orifice plates, in particular, seem to hold considerable promise. They are light, easy to install and move, and do not require excessive head losses. If installation conditions are not found to be too critical for feasible field use, they should gain wide acceptance. Triangular-notch weirs usually can be installed to provide complete contraction and free discharge for measurement of inflow streams. However, the overall head loss requirement limits their use for outflow measurements.

FLOW CONTROL

In order to determine furrow intake rates from inflow-outflow data, the inflow rate should be constant throughout the test. If the inflow rate changes, the volume of water in channel storage in the furrow also changes. The change in channel storage then must be measured in order to determine how much of the flow is going into the soil as intake. Even if intake rate measurements are delayed until the new rate of flow, and the corresponding channel storage, have become stabilized, an extra variable of unknown significance will have been introduced. On some sites the intake rate may be materially affected by the stream size.

Inflow-rate fluctuations can be controlled satisfactorily by the use of overflow weirs and submerged orifice controls as shown in Figure 6. This method of control is further described on page 3 of Agriculture Handbook 82, (April 1956) United States Department of Agriculture, "Methods

CROSS—SECTION DATA

CROSS SECTION LOCATION		POSITION OF MEASUREMENT									
		LEFT OF ℄ - Inches				℄	RIGHT OF ℄ - Inches				
		11	9	6	3		3	6	9	11	
FURROW NO.	STA.	DEPTH MEASUREMENT IN inches									
1	0+50	1¾	2½	3¼	5½	6	5	3	1½	1¼	
1	1+50	1½	2	3¼	5½	6	5	3¼	1½	1	
2	0+50	1¼	2	2¾	5	6	5¼	3¼	2	1¼	
2	1+50	1	1¼	3	5¼	6	4¾	2½	1¼	½	
3	0+50	1¾	2¼	3¼	5¼	6	4¾	2¾	1¼	¾	
3	1+50	2	2½	3½	4¾	6	5½	3½	1¾	1½	
4	0+50	1	1½	2¼	5	6	4¾	2¾	1¼	½	
4	1+50	1¼	2	3	5½	6	5	2¾	1½	½	
TOTAL		11½	16	24¼	41¾	48	40	23¾	12	7¼	
AVERAGE		1½	2	3	5¼	6	5	3	1½	1	

AVERAGE CROSS SECTION

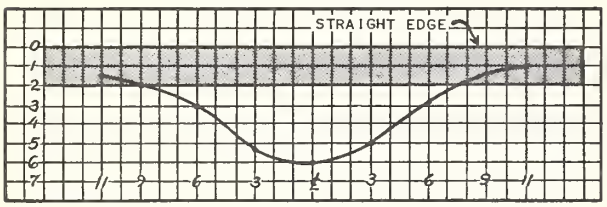

FIGURE 7 : *Sample furrow cross section data and average cross section.*

FURROW INTAKE TEST DATA

FARM: William Work SCD: Gooding

COUNTY: Gooding STATE: Idaho LEGAL DESC: Sec. 14, T. 6S., R. 14E.

SOIL TYPE: Parrott fine sandy loam MAP SYMBOL: 1S 54

CROP: Sugar Beets STAGE OF GROWTH: 6" to 10" high

FURROW SPACING: 22 inches DATE OF TEST: 6/23/57

SOIL MOISTURE: % OF AVAILABLE 1ST FT. 30% 2ND FT. 50%

NO. OF PREVIOUS IRRIGATIONS THIS SEASON 2 SINCE CULT. 0

GENERAL COMMENTS: In potatoes 1956 following 4 years of alfalfa. Beets cultivated on June 20. Ave. furrow grade = 0.75%. Furrows generally smooth and uniform.

FURROW PROFILE AND RATE OF ADVANCE

STA.	ELEV.	FURROW GROUP NO. 1		NO. 2		NO. 3		NO. 4	
		CLOCK TIME	ELAPSED TIME	CLOCK TIME	ELAPSED TIME	CLOCK TIME	ELAPSED TIME	CLOCK TIME	ELAPSED TIME
	FT.		MIN.		MIN.		MIN.		MIN.
0+00	9.9	8:30	START	8:30	START	8:30	START	8:30	START
0+50	9.6	8:31	1	8:32	2	8:31	1	8:31	1
1+00	9.2	8:33	3	8:34	4	8:32	2	8:33	3
1+50	8.8	8:35	5	8:36	6	8:34	4	8:36	6
2+00	8.4	8:37	7	8:38	8	8:36	6	8:38	8

TECHNICIAN: John Doe

FIGURE 8 : *Furrow intake test data.*

for Evaluating Irrigation Systems." Also, where water is delivered to the furrows through gated surface pipe, fluctuations in rates of flow can be reduced by using overflow stands or float valves to control the pressure head in the pipe.

A little extra time spent in setting up the facilities needed to insure satisfactory flow control will return big dividends. Many times in the past inflow-outflow measurements, made without adequate flow control, have been found worthless because the wide fluctuations in streamflow would not permit reliable determinations of instantaneous rates of intake.

INSTALLATION

1. Select the exact furrow sections to be used in the study, and determine the location of the inflow and outflow measuring devices. At least four furrows, or furrow groups, should be measured on each test site. Adjacent furrows should be used, and water should be run in a buffer furrow on each side of the test area.

2. Install the water control facilities needed to maintain a constant inflow into the test furrows. Where water is supplied from an open ditch, a ditch gate, similar to the Ames Type 5, is satisfactory for use in controlling flows from the irrigation head ditch into a secondary ditch or equalizing basin. This ditch gate is made like a gated furrow tube. It is a 6-inch diameter pipe about 4 feet long equipped with a metal slide gate at one end. A box spile, made of 1 x 6 lumber and equipped with a sheet metal or wooden slide gate, also can be used. Siphons or gated spiles usually are used to control flows into the individual furrows. Three-inch-diameter spiles are adequate for flows up to about 60 or 70 gallons per minute. Smaller spiles sometimes can be used. Canvas dams, metal ditch checks, or short pieces of lumber can be used to form stabilized overflow crests.

3. Install the inflow and outflow measuring devices. Check elevations to be sure spiles used for delivery of water for volumetric measurement will have a free discharge and will not cause objectionable ponding. Also, check Parshall free-flow flume settings to be sure they will not be submerged and will not cause an objectionable amount of ponding.

4. Determine the exact length of furrow between the inflow and outflow measuring stations. Set stakes at 25 to 100 foot spacing, with the inflow measuring device at station 0+00. Use spacing that will provide at least three intermediate stations between measuring devices.

5. Determine the furrow profile and the furrow cross section. Take profile shots at each staked point from the inflow station to the outflow station. Adequate cross section measurements usually can be obtained by measuring down from a lath or other straight edge laid in a

level position from one ridge to the next, as shown in Figure 7. Horizontal and vertical datum points should be in the same relative position for all cross sections. Cross sections should be measured at representative points (usually two or three) in each test furrow or furrow group.

6. Determine the required water supply. The maximum flow turned into each furrow should not exceed the nonerosive stream criterion:

$$Q = 10/S, \text{ where}$$

Q is the furrow stream in gallons per minute and S is the furrow slope in percent. The minimum flow to be used should be large enough to produce a fairly uniform rate of advance. For most conditions, furrow streams between one-half and three-fourths of the maximum nonerosive stream, as computed from the above formula, will be found satisfactory. On slopes less than 0.5 percent, stream sizes may be further limited by the capacity of the furrow. When multiple furrow layouts are used (illustrated in Figure 1), the inflow must be sufficient to provide the above described stream in each individual furrow. Also, when replicated tests are made to evaluate the intake characteristics of a particular kind of soil, the furrow streams should be about the same at all sites. In these tests the largest stream should not be more than 50 percent greater than the smallest stream.

OPERATION

1. Turn on the water. Where a control arrangement similar to that shown in Figure 6 is used, the flow in the head ditch usually should be about 25 percent more than will be needed to supply the test furrows. The excess water will be discharged over the weir notch and considerable fluctuation in flow can occur without materially affecting the flow into the equalizing basin.

2. When the flow in the main supply ditch is fairly well stabilized, open the gate into the equalizing basin. The flow into this basin should be slightly in excess of the total needed for the study furrows.

3. When water begins to spill over the overflow notch in the equalizing basin, open the gated spiles that control the flows into the individual furrows. Record the time water starts flowing in each furrow. See Figure 8. Adjust spile gates so the flows into all furrows are approximately equal. The flows can be equalized by making preliminary measurements at the inflow measuring station.

4. Record the time when each furrow stream reaches each intermediate staked station and the time when each furrow stream reaches the outflow measuring station. See Figure 8.

5. Measure each furrow (or furrow group) stream at the inflow measuring station and record the time of measurement and the filling time or head as appropriate for the measurement method being used. Make additional inflow measurements at 15 to 30-minute intervals and record. See Figure 9. Make minor flow control adjustments if found necessary to maintain constant inflow rates.

FURROW INTAKE TEST
INFLOW MEASUREMENT

FURROW GROUP NO. 1			FURROW GROUP NO. 2			FURROW GROUP NO. 3			FURROW GROUP NO. 4		
STA. 0+00			STA. 0+00			STA. 0+00			STA. 0+00		
CLOCK TIME	Sec. *	FLOW GPM	CLOCK TIME	Sec. *	FLOW GPM	CLOCK TIME	Sec. *	FLOW / GPM	CLOCK TIME	Sec. *	FLOW GPM
8:30	22.5	8.0	8:30	24.3	7.4	8:30	22.5	8.0	8:30	23.1	7.8
8:35	22.5	8.0	8:36	24.0	7.5	8:38	21.4	8.4	8:39	23.7	7.6
8:45	22.5	8.0	8:47	24.0	7.5	8:50	21.4	8.4	8:52	23.7	7.6
9:00	22.5	8.0	9:05	24.0	7.5	9:10	21.4	8.4	9:12	23.7	7.6
9:30	22.5	8.0	9:31	24.0	7.5	9:33	21.4	8.4	9:35	23.7	7.6
10:00	22.5	8.0	10:01	24.0	7.5	10:03	21.4	8.4	10:05	23.7	7.6
10:30	22.5	8.0	10:32	24.0	7.5	10:35	21.4	8.4	10:37	23.7	7.6
11:00	22.5	8.0	11:03	24.0	7.5	11:05	21.4	8.4	11:06	23.7	7.6
12:00	22.5	8.0	12:05	24.0	7.5	12:10	21.4	8.4	12:11	23.7	7.6
12:15	22.5	8.0	12:30	24.0	7.5	12:40	21.4	8.4	12:44	23.7	7.6
** 3 Gallon Bucket			** 3 Gallon Bucket			** 3 Gallon Bucket			** 3 Gallon Bucket		

*SHOW MEASUREMENT UNIT. **SHOW SIZE AND TYPE OF MEASURING DEVICE

FIGURE 9 : *Furrow intake test. Inflow measurements.*

FURROW INTAKE TEST

OUTFLOW MEASUREMENT

FURROW GROUP NO. 1			FURROW GROUP NO. 2			FURROW GROUP NO. 3			FURROW GROUP NO. 4		
STA.. 2+00			STA. 2+00			STA. 2+00			STA. 2+00		
CLOCK TIME	Sec. *	FLOW GPM	CLOCK TIME	Sec. *	FLOW GPM	CLOCK TIME	Sec. *	FLOW GPM	CLOCK TIME	Sec. *	FLOW GPM
8:40	41.0	4.39	8:45	44.6	4.04	8:42	36.4	4.94	8:52	38.8	4.64
8:50	34.7	5.20	8:55	41.5	4.34	8:48	32.8	5.49	9:02	37.6	4.78
9:00	32.3	5.58	9:20	37.0	4.86	9:05	30.0	6.00	9:10	36.1	4.98
9:15	31.1	5.80	9:40	36.4	4.94	9:25	28.0	6.43	9:35	34.4	5.24
9:30	30.0	6.00	10:05	35.3	5.10	9:55	26.8	6.72	9:58	33.3	5.40
10:00	29.0	6.20	10:35	34.5	5.22	10:25	26.3	6.84	10:40	32.2	5.60
10:30	28.6	6.30	11:05	33.6	5.36	10:55	25.9	6.95	11:10	31.8	5.66
11:00	28.2	6.40	11:40	33.6	5.36	11:25	25.5	7.06	11:35	31.5	5.72
11:32	27.8	6.50	12:10	33.2	5.42	12:00	25.2	7.14	11:55	31.1	5.78
12:05	27.5	6.54	12:20	33.2	5.42	12:30	25.0	7.20	12:40	30.8	5.84
** 3 Gallon Bucket			** 3 Gallon Bucket			** 3 Gallon Bucket			** 3 Gallon Bucket		

*SHOW MEASUREMENT UNIT. **SHOW SIZE AND TYPE OF MEASURING DEVICE.

FIGURE 10 :| *Furrow intake test. Outflow measurements.*

6. After flows in the furrow test sections become stabilized (generally 5 to 10 minutes after water begins to flow through the outflow measuring devices), measure the outflow of each furrow (or furrow group). Record the time of measurement and the filling time or head. Make additional outflow measurements as needed to define the changes in outflow rate. See Figure 10. Usually these additional measurements should be made at about 10 to 15-minute intervals for the first hour and then at 20 to 60-minute intervals to the end of the test. Intake tests should be run long enough to define the shape of the intake rate curve. On coarse textured soils, 1 or 2 hours may be adequate. Two to 4 hours usually are required on medium textured soils; fine textured soils usually require 4 to 10 hours.

7. Turn off the water and remove and clean equipment.

COMPUTING and PLOTTING DATA

1. Compute the inflow and outflow rates for each recorded measurement of "head" for Parshall flumes or each recorded "time to fill container" for volumetric measurements. (See Figures 9 and 10.)

2. Compute "loss in furrow" for the measured reach and "intake rate per 100 feet of furrow" for each time when outflow measurements were made. Also compute the average elapsed intake opportunity time for each of these intake rate values. If the rate of advance is nearly uniform, this average elapsed time can be taken as the arithmetic average of the time water was in the upper and lower ends of the test section. See Figure 11.

3. Plot intake rate values against average elapsed time. Use logarithmic paper. Draw best-fit straight lines through the plotted points and determine the equations for these lines. On log paper the intake rate curves are represented by the general formula $I = KT^n$, where I is the instantaneous intake rate, K is the intake rate at unit time, T is the average elapsed intake opportunity time for the furrow, and n is the measured slope of the line (vertical/horizontal). Figure 12 shows the intake rate curves for the sample data from Figure 11.

4. Plot an average instantaneous intake rate curve for the site. The average curve will have K and n values equal to the average of the individual furrows. See Figure 12.

5. Determine the basic intake rate for the site. The basic intake rate is the rate at elapsed time equal to -600n.

6. If desired, compute and plot equivalent field intake rate curves for various furrow

FURROW GROUP NO. 1

CLOCK TIME	ELAPSED TIME: INFLOW STATION	ELAPSED TIME: OUTFLOW STATION	ELAPSED TIME: FURROW AVERAGE	INFLOW	OUTFLOW	LOSS IN FURROW 200 FT.	INTAKE PER 100 FT.
	MIN.	MIN.	MIN.	GPM	GPM	GPM	GPM
8:30	START	–	–	8.0	–	–	–
8:37	7	0	4	8.0	0.00	–	–
8:40	10	3	7	8.0	4.39	3.61	1.80
8:50	20	13	17	8.0	5.20	2.80	1.40
9:00	30	23	27	8.0	5.58	2.42	1.21
9:15	45	38	42	8.0	5.80	2.20	1.10
9:30	60	53	57	8.0	6.00	2.00	1.00
10:00	90	83	87	8.0	6.20	1.80	0.90
10:30	120	113	117	8.0	6.30	1.70	0.85
11:00	150	143	147	8.0	6.40	1.60	0.80
11:32	182	175	179	8.0	6.50	1.50	0.75
12:05	215	208	212	8.0	6.54	1.46	0.73

FURROW GROUP NO. 3

CLOCK TIME	ELAPSED TIME: INFLOW STATION	ELAPSED TIME: OUTFLOW STATION	ELAPSED TIME: FURROW AVERAGE	INFLOW	OUTFLOW	LOSS IN FURROW 200FT.	INTAKE PER 100 FT.
	MIN.	MIN.	MIN.	GPM	GPM	GPM	GPM
8:30	START	–	–	8.0	–	–	–
8:36	6	0	3	8.4	0.00	–	–
8:42	12	6	9	8.4	4.94	3.46	1.73
8:48	18	12	15	8.4	5.49	2.91	1.46
9:05	35	29	32	8.4	6.00	2.40	1.20
9:25	55	49	52	8.4	6.43	1.97	0.99
9:55	85	79	82	8.4	6.72	1.68	0.84
10:25	115	109	112	8.4	6.84	1.56	0.78
10:55	145	139	142	8.4	6.95	1.45	0.72
11:25	175	169	172	8.4	7.06	1.34	0.67
12:00	210	204	207	8.4	7.14	1.26	0.63
12:30	240	234	237	8.4	7.20	1.20	0.60

FURROW GROUP NO. 2

CLOCK TIME	ELAPSED TIME: INFLOW STATION	ELAPSED TIME: OUTFLOW STATION	ELAPSED TIME: FURROW AVERAGE	INFLOW	OUTFLOW	LOSS IN FURROW 200FT.	INTAKE PER 100 FT.
	MIN.	MIN.	MIN.	GPM	GPM	GPM	GPM
8:30	START	–	–	7.4	–	–	–
8:38	8	0	4	7.5	0.00	–	–
8:45	15	7	11	7.5	4.04	3.46	1.73
8:55	25	17	21	7.5	4.34	3.16	1.58
9:20	50	42	46	7.5	4.86	2.64	1.32
9:40	70	62	66	7.5	4.94	2.56	1.28
10:05	95	87	91	7.5	5.10	2.40	1.20
10:35	125	117	121	7.5	5.22	2.28	1.14
11:05	155	147	151	7.5	5.36	2.14	1.07
11:40	190	182	186	7.5	5.36	2.14	1.07
12:10	220	212	216	7.5	5.42	2.08	1.04
12:20	230	222	226	7.5	5.42	2.08	1.04

FURROW GROUP NO. 4

CLOCK TIME	ELAPSED TIME: INFLOW STATION	ELAPSED TIME: OUTFLOW STATION	ELAPSED TIME: FURROW AVERAGE	INFLOW	OUTFLOW	LOSS IN FURROW 200FT.	INTAKE PER 100 FT.
	MIN.	MIN.	MIN.	GPM	GPM	GPM	GPM
8:30	START	–	–	7.8	–	–	–
8:38	8	0	4	7.6	0.00	–	–
8:52	22	14	18	7.6	4.64	2.96	1.48
9:02	32	24	28	7.6	4.78	2.82	1.41
9:10	40	32	36	7.6	4.98	2.62	1.31
9:35	65	57	61	7.6	5.24	2.36	1.18
9:58	88	80	84	7.6	5.40	2.20	1.10
10:40	130	122	126	7.6	5.60	2.00	1.00
11:10	160	152	156	7.6	5.66	1.94	0.97
11:35	185	177	181	7.6	5.72	1.88	0.94
11:55	205	197	201	7.6	5.78	1.82	0.91
12:40	250	242	246	7.6	5.84	1.76	0.88

FIGURE 11 : *Furrow intake test. Computation of furrow intake rate.*

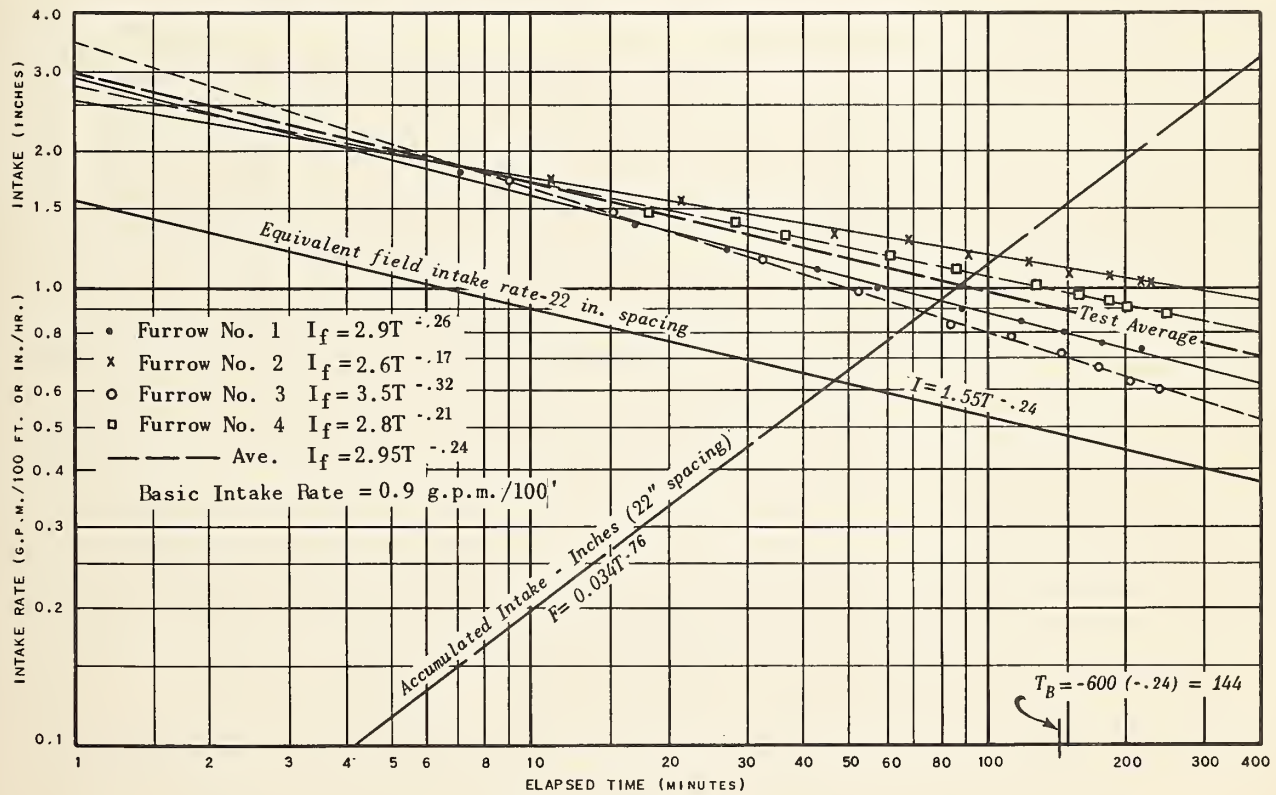
INTAKE (INCHES)
INTAKE RATE (G.P.M./100 FT. OR IN./HR.)
ELAPSED TIME (MINUTES)
Equivalent field intake rate-22 in. spacing
Test Average
I = 1.55T -.24
Accumulated Intake - Inches (22" spacing)
F= 0.034T .76
Furrow No. 1 If = 2.9T -.26
Furrow No. 2 If = 2.6T -.17
Furrow No. 3 If = 3.5T -.32
Furrow No. 4 If = 2.8T -.21
Ave. If = 2.95T -.24
Basic Intake Rate = 0.9 g.p.m./100'
TB = 600 (-.24) = 144

FIGURE 12 : *Sample intake curves.*

spacings. The equivalent field intake rate can be computed from the formula:

$$I = \frac{11.55 I_f}{w}$$, where

I = Equivalent field intake rate in inches per hour.

I_f = Furrow intake rate in gallons per minute per 100 feet

w = Furrow spacing in inches

7. If desired, compute and plot the accumulated intake curves from the equivalent field intake rate curves. The intake is equal to the area under the intake rate curve and can be computed by integration. Thus, if the intake rate (I) is equal to KT^n, the intake (F), for time in minutes, will be equal to:

$$\frac{K}{60(n+1)} T^{n+1}$$

(See Figure 12)